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Multi-scale pore network model for simulation of multi-phase flow in heterogeneous porous media

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Pore network modelling as a robust and powerful technique has been used to study multiphase flow through porous media for many years. Micro-CT imaging makes it possible to acquire actual pore structure geometry used to extract the pore network structure. Also, multiphase micro-CT images can be used to calibrate the pore-scale distribution of wettability. However, in many kinds of porous media both in nature and industry, the pore size distribution covers many orders of magnitude in length scales where it is not possible to resolve all the pore space in a single image. For example, micron-resolution imaging of a sample a few mm to cm across cannot explicitly resolve sub-micron porosity which may have a significant impact on flow behaviour. Therefore, considering sub-resolution pore space in pore network modelling is necessary.

Experimentally, differential micro-CT imaging, comparing a dry image with an image of a sample completely saturated with a contrast fluid (usually a high-concentration brine) allows porosity to be quantified voxel-by-voxel. In this study, we have developed a workflow to incorporate unresolved porosity in our modelling. For this purpose, wherever the micro-porous region (with a voxel porosity less than 1 but greater than zero) connects to resolved pore space (voxel porosity of 1) a micro-link is considered. An automatic parallelized algorithm helps to identify micro-links incorporated in the pore network extracted from resolved pores. While resolved pores are treated similarly to a conventional pore network model, the micro-links are treated as continuum Darcy-type porous media in which empirical correlation are be used to determine their parameters. Due to the uncertain nature of the unresolved pore space, we tune the parameter of the empirical models to match observed experimental behaviour, such as permeability and primary drainage capillary pressure, using a multiscale pore network model. Finally, we applied this workflow to model multiphase flow in Estaillades limestone and a complex reservoir rock sample in which more than 50% of the pore space is unresolved in our micro-CT images, and simulation using multi-scale model is necessary.

Participation

In-Person

References

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